USING TRAINED POUCHED RATS TO DETECT LAND MINES: ANOTHER VICTORY FOR OPERANT CONDITIONING

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We used giant African pouched rats (*Cricetomys gambianus*) as land mine-detection animals in Mozambique because they have an excellent sense of smell, weigh too little to activate mines, and are native to sub-Saharan Africa, and therefore are resistant to local parasites and diseases. In 2009 the rats searched 93,400 m^2 of land, finding 41 mines and 54 other explosive devices. Humans with metal detectors found no additional mines. On average, the rats emitted 0.33 false alarm for every 100 m^2 searched, which is below the threshold given by International Mine Action Standards for accrediting mine-detection animals. These findings indicate that *Cricetomys* are accurate mine-detection animals and merit continued use in this capacity.

Key words: land mines, pouched rats, applied behavior analysis, animal learning, olfaction

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Military and paramilitary forces have planted millions of land mines since 1900. Many remain and do great harm by denying civilians access to their homes and land, as well as by causing bodily harm, death, and psychological duress. People in more than 70 countries are adversely affected by mined areas, and nearly 500,000 people live with injuries inflicted by mines (Landmine Monitor Report, 2009). Victims often are both severely handicapped and unable to afford the rehabilitation and other services that they need.

Demining hazardous areas is important, but it is also costly and time consuming. Demining is accomplished through the use of mechanical devices, such as armored automotive tillers and flails or handheld metal detectors, and with the help of animals, usually trained dogs (Geneva International Centre for Humanitarian Demining, 2007). In recent years, researchers have explored the possibility of using giant African pouched rats (*Cricetomys gambianus*) as demining animals in Africa. The rats have an excellent

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Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling (APOPO) is a Belgian nongovernmental organization based in Tanzania. Its personnel train giant African pouched rats for humanitarian odor-detection applications. Support for APOPO's mine-detection work has been provided by Antwerp University (Belgium), Sokoine University of Agriculture (Tanzania), the United Nations Development Programme, and the Belgian government.

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sense of smell and are native to sub-Saharan Africa and therefore are resistant to local parasites and diseases. Moreover, they weigh too little to activate most mines and have long working lives (up to 6 years). Finally, behavior analysts and other researchers have long studied the operant behavior of rats (e.g., Skinner, 1938, 1953), although not specifically *Cricetomys,* and have developed excellent procedures for training the animals (e.g., Iversen & Lattal, 1991a, 1991b). Operant discrimination training has been shown to be successful in teaching *Cricetomys* to search for land mines in a simulated minefield (Verhagen, Cox, Mauchango, Weetjens, & Billet, 2003) and in limited tests on an actual minefield (Verhagen, Weetjens, Cox, Weetjens, & Billet, 2006). We describe herein their performance during 2009 in demining operations in Gaza Province, Mozambique, where mines were placed during the civil war that ended in 1992. Our experimental question was: What is the miss rate of pouched rats used operationally for mine detection? Failures to find mines (misses) are a serious safety concern, and a zero miss rate is always desired although sometimes unattainable (Guelle, Smith, Lewis, & Bloodworth, 2003).

METHOD

Subjects

Cricetomys are nocturnal burrowing natives of sub-Saharan Africa. Adults have body lengths of 25 to 45 cm and weigh 1 to 2 kg. Our rats were born and trained in Morogoro, Tanzania. From 4 to 6 weeks of age, pups were socialized by being extensively handled and exposed to a variety of stimuli. Their training occurred over approximately 185 days (see also Poling, Weetjens, Cox, Beyene, & Sully, 2010a, 2010b, for a description).

Training

Clicker training, in which a sound was repeatedly presented just before food to establish it as a conditioned reinforcer as well as a discriminative stimulus for approaching handlers, occurred after the initial socialization. Initial response training took place in a metal cage that contained a 2-cm hole in the floor below which a positive training sample was presented. This sample, presented in a small pot, consisted of 2 g of sandy soil to which up to five drops of aqueous 2,4,6-trinitrotoluene (TNT; 100 ng per microliter) was added. (TNT is the main explosive charge in the majority of land mines.) The trainer sounded a click and presented a mouthful of mashed bananas mixed with crushed rat chow through a plastic syringe if the rat placed its nose in the hole for 2, and later 5, consecutive seconds. Multiple daily trials occurred until the rat placed its nose in the hole within 5 s of being put in the cage and kept it there for the required number of seconds on 10 consecutive tests, after which discrimination training began. In all stages, correct and incorrect responses were recorded by each rat's trainer.

Discrimination training began in a three-hole cage, which allowed positive and negative samples to be presented. Positive samples were as just described, whereas negative samples consisted of 2 g of sandy soil spiked with water. During initial discrimination training, half of the pots contained TNT-contaminated soil and half contained plain soil. The trainer sounded a click and delivered food on each trial that a rat kept its nose in a hole above TNT for 5 s, but not at any other time. Training with 60 to 90 samples per day continued until a rat consistently emitted the indicator response on 100% of occasions when TNT was present and on no more than one occasion when TNT was absent.

Next, the rats were exposed to a procedure in which perforated stainless steel balls (tea eggs), some that contained TNT and some that did not, were placed with the rat on a solid platform (0.75 cm by 3 m) with high sides and covered with soil. The rat received a reinforcer (click and banana) only if it bit or dug at a tea egg that contained TNT. Once it reliably did so, the tea eggs were buried up to 1 cm deep, and training continued until the rat emitted the indicator response to all tea eggs that contained TNT and to no tea egg that did not contain it on at least 2 consecutive days. The rat then proceeded to field training, which was conducted on a 28-hectare simulated minefield with 1,533 defused land mines of several types that the Tanzanian military buried just below the surface in 2001 through 2004.

Field training began in areas (3 m wide by 10 m long), termed *boxes,* that had been cleared of all vegetation. Five to 10 tea eggs that contained TNT were partially buried in each box, and the rats' task was to detect them. A similar number of tea eggs containing nothing or one of a variety of other chemical compounds were also buried in each box. The location and type (TNT or not) of each egg were recorded. An important first step in field training was to teach the rats to move back and forth along the length of a rope suspended between two trainers, who periodically moved the rope forward. The rat wore a nylon harness with a metal snap connector to which one end of a thin nylon line was attached. The other end was looped around the rope stretched between the trainers. The trainers held thin lines attached to the rat's harness cord and moved the rat along the rope by pulling on one line and feeding out the other. The rat quickly learned to move independently from side to side along the rope and to search every area of a box as the trainers moved forward.

If a rat paused at a tea egg that contained TNT and scratched or bit near that egg for at least 5 s, the trainer sounded the clicker and presented food. If this indicator response occurred near a tea egg that did not contain TNT, the reinforcer was not presented and the rat was pulled away. Each rat searched two boxes every day. Training continued until every egg engendered an appropriate indicator response and no other indicator responses occurred. Thereafter, the rat was trained in boxes (3 m wide) that contained zero to five defused land mines. All boxes were kept clear of tall vegetation (>5 cm) by hand cutting.

Numbered metal stakes defined the boundaries of individual boxes; these allowed specification of a rat's location at any time in terms of two coordinates. The coordinates of all mines were known. Trainers recorded hits (indicator responses within 1 m of a mine) and immediately reinforced such responses with a click and, after the rat came close enough, a mouthful of mashed bananas. Trainers also recorded indicator responses further from mines (false alarms) but did not reinforce them. Training continued in this fashion, with rats exposed to two boxes per day, until a rat completed a box having correctly identified all of the mines with no false alarms. At that point, it moved to a larger box (5 m wide) and training proceeded as described above. When the same performance criterion was met, the animal was moved to 100-m^2 boxes and the procedure was repeated. Once criterion was met in the 100-m^2 box, the rat was given a blind test, in which the trainers did not know the location of mines. To pass, the rat had to identify all of the mines in four 100-m^2 boxes, each containing zero to four mines, with no more than two false alarms. Only rats that passed this test (nearly all [<95%] of them that reach this stage of testing do so) were used in Mozambique.

An APOPO team of 50 people and 34 pouched rats accredited as mine-detection animals (see below) engaged in demining operations in 2009. After the rats arrived in Mozambique, their training continued on a simulated minefield. When a rat's performance stabilized, an accreditation test was performed with the help of the National Mine Action Authority (NMAA). To pass, a rat had to detect every mine in a 200-m^2 test area that contained five to seven mines with two or fewer false alarms. It was then licensed as an operational mine-detection animal by the NMAA. All of the 34 rats used in this study were licensed.

Demining

A large armored brush cutter cleared vegetation to a height that allowed the rats to move easily. Deminers wearing protective gear used metal detectors to clear well-marked paths through the hazardous area. These paths were spaced so as to construct a series of rectangular boxes 10 m wide and 20 m long. Two rats serially searched each box using the rope system previously described. Handlers recorded all indicator responses on a grid that represented the box in *x* and *y* coordinates. Nylon straps marked at 1-m intervals stretched along the sides of the box allowed coordinates to be estimated accurately. Because it was not known whether indicator responses were hits or false alarms, no reinforcers were delivered during actual demining. Reinforcers received on the simulated minefield and following a successful search for a mine buried at the edge of a box at the beginning of each working day were sufficient to sustain performance. The number of square meters searched by the rats, the number of mines and explosive remnants of war (ERW, e.g., mine fuses) located by the rats, the total area made accessible to humans, and the number of hits and false alarms were recorded. A person using a sensitive metal detector searched for mines in the location of all indicator responses and also examined all other areas previously checked by the rats, including those where no indicator responses occurred. All mines located were extracted and destroyed.

RESULTS AND DISCUSSION

The rats searched a total of 93,400 m^2 in 2009, and this land was subsequently made available for the use of local people. The rats located a total of 41 mines. Humans with metal detectors found no mines beyond those located by the rats. Thus, the miss rate was 0% for the group of 34 rats and for each individual rat. Multiple locator responses often were observed in the vicinity of a given mine. This is unsurprising, because the mines had been buried for two decades in sandy soil, affording ample opportunity for the distribution of detectable chemicals. Indicator responses also occurred in areas in which no mines were found, but 54 other ERW were located. These devices contain chemicals like those found in land mines and are dangerous in their own right. Therefore, locating them was an added benefit.

For the entire area checked by the rats (93,400 m^2), 617 false alarms were recorded. Teams of two rats searched every box, so the total searched by the 34 rats individually was 186,800 m^2. It is convention in humanitarian demining to express false alarm rates in terms of false alarms per 100 m^2, and our rats' false alarm rate was 0.33 per 100 m^2 searched. International Mine Actions Standards 09.42 (2008) for accrediting mine-detection animals specify that animals can emit no more than two false alarms in a single test search of a 400-m^2 area. Our rats as a group, and each individual rat, met this criterion in operational service over a 1-year period.

Although it is standard practice in demining to conduct quality assurance checks by using a second method to search for mines missed in an initial search, the area checked usually is a small percentage of the total area. The present findings apparently are the first report of quality assurance data for an entire demined area of substantial size. They indicate that *Cricetomys* are accurate mine-detection animals and merit continued use in this capacity. Their success in detecting mines was the result of the careful application of fundamental principles of operant behavior. Although these principles were used in a context unlike that characteristic of mainstream applied behavior analysis, the end result was substantial benefit to humanity and another victory for operant conditioning.

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